# Preconditioning for Combustion Problems with Detailed Chemical Mechanisms

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**Abstract**

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*Keywords:* Preconditioning, Dual timestepping, Chemically reactive flow

## 1. Introduction

Time-accurate integration of low-Mach combustion is difficult because of the inherent stiffness between kinetic, acoustic, advective, and diffusive time scales. Tight coupling between high- and low-frequency modes places severe constraints on traditional solution techniques, particularly when employing highly-detailed chemical reaction mechanisms.

Preconditioned dual timestepping has enjoyed success as a tool for simulation of all-Mach number flows(citations here).

Extension of this methodology to chemically reactive flows has seen little development. Venkateswaran et al. [3] unsuccessfully attempted to apply time-derivative scaling of the species equations. Sankaran and Oefelein [2] consider the eigenvalues of a one-step combustion mechanism in developing their preconditioning strategy. Their results show success in accelerating convergence of a 16-species, 12-reaction mechanism for methane-air combustion. In this paper we develop and test new preconditioning heuristics for the chemical source terms. We compare results against the preconditioners of Venkateswaran et al. [3], Sankaran and Oefelein [2].

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## 2. Conclusions

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## 3. Acknowledgement

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## 4. References

[1] I. Elmahi, O. Gloth, D. Hanel, R. Vilsmeier, A preconditioned dual time-stepping method for combustion problems, International Journal of Computational Fluid Dynamics 22 (3) (2008) 169–181.

[2] V. Sankaran, J. Oefelein, Advanced preconditioning strategies for chemically reacting flows, in: 45th AIAA Aerospace Sciences Meeting and Exhibit, 2, AIAA, Reno, NV, Paper 2007–1432, 2007.

[3] S. Venkateswaran, M. Deshpande, C. Merkle, The Application of Preconditioning to Reactive Flow Computations, in: 12th AIAA Computational Fluid Dynamics Conference, AIAA 95-1673-CP, 306–316, 1995.